



Outcomes from a STEM Education Program for Elementary School Students in Medically Underserved Areas and Populations

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Abstract

Early exposure to science, technology, engineering, and mathematics (STEM) can inspire children from medically underserved areas and populations (MUA/P) to pursue health and biomedical careers, helping reduce long-term cancer disparities. The Georgetown University Lombardi Comprehensive Cancer Center and KID Museum co-developed the Young Scholars Program (YSP) to engage elementary students from Title I schools in the Washington, DC region, in hands-on learning about cancer biology and prevention through a maker education approach. This study evaluated the YSP's impact on students' inventive learning, sense of belonging in STEM, and STEM interest using mixed methods. During the 2024–2025 school year, $N=432$ students from four Title I schools participated. Most identified as Black (35%) or Latine (53%), and 49% were female. Among program attendees, $N=306$ completed exit tickets, $N=224$ returned evaluation surveys, and $N=184$ had exit tickets matched to surveys. Post-program, nearly all students reported practicing as a scientist (99%) or engineer (98%). Knowledge of cancer biology and prevention was high, with 88–96% answering key questions correctly. Students endorsed strong inventive learning (90%), belonging in STEM (92%), and STEM interest (81%). Among students with matched data, those who reported practicing as scientists or engineers showed significantly greater inventive learning ($F=16.19$, $p<0.001$), belonging ($F=9.65$, $p=0.002$), and STEM interest ($F=4.75$, $p=0.03$). Qualitative reflections ($N=284$ responses) most frequently described initiative (48%), followed by skill building (19%), teamwork (17%), perspective-taking (11%), and exploration (5%). The YSP strengthened students' STEM identity, comprehension of cancer concepts, and engagement in maker learning. Hands-on, culturally relevant instruction fostered initiative, collaboration, and belonging. Community-based STEM programs like the YSP show promise for advancing early STEM engagement and diversifying the future biomedical workforce.

Background

Introducing children to science, technology, engineering, and math (STEM) at a young age can inspire them to pursue careers in STEM as adults [1]. Childhood STEM education is especially important for youth from medically underserved areas and populations (MUA/P) who are not well-represented in STEM fields, including healthcare and medicine [2]. According to the Health Resources and

Services Administration of the U.S. Department of Health and Human Services, a MUA/P refers to regions or groups with shortages of primary care services and additional barriers to healthcare, such as economic, cultural, or linguistic challenges [3, 4]. These shortages are compounded by workforce disparities; for instance, less than half of U.S. counties have at least one Black primary care physician [5]. For MUA/P, research has illustrated that patient-provider racial concordance leads to higher life expectancy, better communication, fewer visits to the emergency room, and are more likely to adhere to their medication regimen [6–8]. Thus, supporting STEM and medical pathways for such students could have lasting benefits for the health of their communities by helping to address persistent health disparities, including inequities in cancer incidence, treatment, and outcomes [9].

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From an educational perspective, research suggests that encouraging students from MUA/P to pursue careers in STEM should start early in childhood. A student's STEM identity, or the extent to which they associate with or connect as a member of a STEM field, begins to form as early as elementary school, underscoring the need for early STEM education to help broaden opportunities for students from MUA/P [2]. Feelings of belonging are a key part of STEM identity, making it especially important for children from MUA/P to feel included in STEM groups and spaces to support their interest, confidence, and persistence in STEM [10]. Programs designed to help young children from MUA/P envision themselves as scientists or engineers can reduce stereotypical images of scientists and potentially increase long-term STEM interest [11–13]. Gaining a sense of belonging in STEM fields among underrepresented populations has also been shown to increase children's desire to pursue these careers in the future, making children's sense of belonging an important mechanism to increase equitable representation in the STEM workforce [14–16].

The Young Scholars Program (YSP), created by Georgetown University Lombardi Cancer Center and KID Museum, aims to address this issue by bringing students attending Title I-eligible elementary schools in MUA/P in the Washington, DC area on a day-long field trip to the museum [17]. KID Museum is a nonprofit organization dedicated to building STEM and creative problem-solving skills through hands-on learning experiences [18]. In the District of Columbia, for example, schools are Title I-eligible if 35% or more of its students live below the poverty line, which includes 88 of 117 public schools [19]. Nationwide, Title I schools receive federal funding to strive for equal education opportunities for low-income students. However, educational inequalities persist: compared to non-Title I schools, students have math and reading scores that are significantly lower than those who attend non-Title I schools [20]. In the District of Columbia, 89.4% of Black students and 80.8% of Latine students attend a Title I school, compared to 25.7% of their white counterparts [21]. Differences in public education, particularly at the elementary level, may further widen the gap between students who pursue higher education in STEM and those who do not. To address this challenge, the YSP partners with the STEM-focused KID Museum to provide elementary students from MUA/P with opportunities to engage in maker learning activities that foster creativity, introduce cancer biology and prevention concepts, and cultivate a sense of belonging in STEM.

Bringing maker learning and STEM experiences to young students from Title I schools can be a powerful strategy to reduce educational inequalities and encourage a STEM workforce that more closely reflects the population. In light of these issues, this report describes the results of

a secondary data analysis of a cohort of 5th graders from Title I schools in the greater Washington, DC metro area who participated in the YSP. The primary purpose was to examine elementary school children's inventive learning, sense of belonging in STEM, and STEM interest, as well as other outcomes of program participation. This predominantly Black and Latine sample provides important insight into the potential of the YSP to foster STEM engagement among students from MUA/P.

Methods

The Young Scholars Program

The YSP was co-created in 2022 by the Georgetown University Lombardi Comprehensive Cancer Center and KID Museum to inspire elementary school students from Title I schools (with high populations of students from MUA/P) in the greater Washington, DC metro area in learning about cancer medicine, biology, and prevention [17]. Co-facilitated by museum educators and volunteer researchers, physicians, and other professionals in STEM fields, the YSP uses a maker learning approach to help students imagine, invent and prototype solutions to problems and situations using STEM concepts and skills such as critical thinking, problem-solving, creativity, and curiosity [22].

Students in the YSP spend a full day at the museum exploring STEM topics, learning about cancer biology and prevention, and building a sense of belonging in STEM spaces. The program has two parts: a maker workshop where students apply the scientific method and engineering design process to address community cancer risk factors, and hands-on activities focused on cell biology, cancer immunology, and ultraviolet radiation exposure. In the cancer prevention activity, YSP students use simple building materials like cardboard to construct shade structures through an iterative design and build process: different sun protection solutions to block ultraviolet radiation are explored. Students test their designs on a small-scale model of a beach where a lamp served as the sun and powered a small fan. If the structure effectively blocked the 'sun's' harmful rays then the fan would stop rotating. If not, students worked with museum educators and cancer center volunteers to re-imagine their design and rebuild their solution while discussing the importance of skin cancer prevention. Similarly, for cell biology, students learned how to prepare slides and use microscopes by exploring how changes (e.g., when heat is applied) in materials (e.g., wood, sandpaper, hair) appear under different levels of magnification. Some changes were explained to be visible to the naked eye, while others required magnification in order to be seen. Students also explored the

mechanics of the human body's immune response by using computer coding to control color-sensitive robots. Robots symbolized white blood cells and students were challenged to activate them to respond to different health conditions on a life-size graphic cutout of a person ("Sick Sam"). Sick Sam had a scratch, a bruise, an infection, a stomach bug, and a sunburn—each represented by a different color. Students who successfully coded their robot (white blood cells) sent it to specific ailments. If unsuccessful, the robot was reprogrammed with guidance from museum educators and cancer center volunteers, who reviewed basic principles of cancer immunology. Each group completes one activity in the morning, then rotates to the other after lunch. In the program, culturally relevant strategies include bilingual (Spanish-English) translation of materials and inclusion of community-relevant cancer topics. Bilingual program evaluations are completed on-site as well as in the classroom when students return to school. For a complete description of the YSP development and its day-long activities, please see Tercyak and colleagues [17].

School District and Student Demographics

During the 2024–2025 academic year, students who participated in the YSP were drawn from four Title I elementary schools within a single public school district in the cancer center's catchment area, serving a diverse population of more than $N = 160,000$ students. Schools' population-level characteristics are presented in Table 1, including gender, racial, and ethnic composition of the combined $N = 479$ students enrolled. According to a federal benchmark, selected schools met criteria for being from MUA/P. As shown, 49%

Table 1 Demographic characteristics of YSP cohort 2024–2025 ($N=476$)

Characteristic	N (%)
Gender	
Male	245 (51)
Female	234 (49)
Race/Ethnicity	
African American	170 (35)
Asian	32 (7)
Caucasian	14 (3)
Hispanic	252 (53)
Multiracial	11 (2)
Special Education	
Yes	51 (14)
No	306 (86)
Emerging Multi-Lingual Learners	
Yes	168 (35)
No	311 (65)

of students in those districts were female, 35% were Black/African American, and 53% were Hispanic/Latine; additionally, 35% were designated by their elementary schools as emerging multi-lingual learners. These populations are among those least represented in STEM education and careers nationwide [23].

Program Performance Domains and Assessments

The YSP's learning outcomes are concentrated in three primary domains: (1) cancer biology and prevention comprehension and recall, (2) students' affiliation with STEM careers, and (3) inventive learning, belonging, and STEM interest. Outcomes were measured through a combination of interactive activities, exit tickets, and take-home surveys [17]. Each exit ticket and take-home survey was assigned a study-specific identifier, which allowed for paired analyses while protecting student confidentiality from the evaluation team.

1. Student Comprehension and Recall

Students were first assessed on their understanding of fundamental cancer biology and prevention concepts at the end of the YSP field trip day through an interactive activity in which students answered three knowledge questions by placing tokens in jars corresponding to their selected responses: (1) "Can the sun's ultraviolet rays hurt your skin cells without giving you a sunburn?", (2) "Can a doctor see a problem in our cells without a microscope?", and (3) "Does your immune system recognize different types of threats to your body?" Students were then polled to individually vote "Yes", "Maybe", or "No" to each item using a token in a jar. Correct responses were taken as a percentage of the whole per item.

2. Affiliation with STEM Careers

Affiliation with STEM careers was measured using an exit ticket (i.e., a brief written slip completed at the end of the program day). This measure consisted of two items measuring students' affiliation with STEM careers: (1) "Today I practiced being a scientist" and (2) "Today I practiced being an engineer." Each item was rated on a three-point scale (1 = "Not at all", 2 = "A little," 3 = "A lot"); students completed and submitted their responses privately to avoid peer or other influences.

3. Inventive Learning, Belonging, and STEM Interest

Inventive learning, belonging, and STEM interest were assessed through a self-report survey administered in students' school classrooms following their museum experience. The bilingual (English, Spanish appearing

side by side) take-home assessment measures were modeled after a suite of tools that were developed, tested, and validated by Noam and colleagues through prior educational research on children engaging with STEM teachings in informal settings [24]. For the present evaluation, inventive learning, students' sense of belonging in STEM, and STEM interest were measured by a 10-item survey completed upon their return to school, and read and facilitated by classroom teachers [17, 18]. Students rated each item on a three-point Likert-type scale using visual indicators; students could circle a frowning face, neutral face, or smiling face that corresponded with each quantifier (1 = "Not at all", 2 = "A little," 3 = "A lot", respectively). These visual indicators, paired with adjectives and quantifiers, along with verbal instructions by teachers to help reduce literacy demands, are reliable and valid ways to assess young children's experiences [25]. Higher item-level scores are considered indicative of more inventive learning, belonging, and STEM career readiness.

Inventive Learning Inventive learning has previously been conceptualized through KID Museum's Mind of a Maker framework which promotes students' development as empathic and persistent problem-solvers, teammates, and agents of change [18]. It includes eight pedagogical constructs: imagination, reflection, perseverance, exploration, initiative, teamwork, perspective-taking, and skill-building. In addition to the in-classroom survey component, students were asked to respond on-site to an open-ended prompt, "My favorite part of today was.". This item provided an opportunity for students to reflect, in their own words and in their preferred language, what aspects of the field trip experience they found most meaningful or resonant.

Belonging Education research indicates that students who feel a stronger sense of belonging within the STEM community may be more likely to engage in continued STEM learning [10]. The YSP facilitates team-based learning where each team member is able to make an active contribution to their group. To do so, KID Museum educators and cancer center volunteers engage every student in a group by encouraging them to work with each other to solve problems before asking for external help. Active participation among students supports and builds their self-confidence in working with others while learning STEM content.

STEM Interest Regarding STEM interest, a young student's passion for learning STEM subjects is another crucial step to both widening the pipeline and increasing the number of students entering STEM professions [17]. The YSP aims

to ignite a student's curiosity about each problem they encounter at the museum while encouraging them to apply knowledge and skills learned at school and at the museum, such as math or science. A student's sustained or increased affinity toward science, building and engineering, inventing, sparked by the experience of the YSP, may facilitate longer term STEM interest.

Data Analysis Plan

All program data were entered, error-checked twice, and screened for statistical assumptions before conducting analyses. Demographic characteristics of the full sample were examined using frequencies, percentages, means, and standard deviations. For student comprehension and recall, responses of "Maybe" were included with the correct response for all items. For STEM affiliations and inventive learning, success in advancing YSP's objectives was defined as student responses of "A little" or "A lot" combined. Combining response options in this manner ensured adequate cell sizes for statistical analysis to proceed and simplified interpretations given the developmental stage of the children who provided the data.

Quantitative analyses were conducted in two stages. First, univariate, bivariate, and reliability analyses were performed on the full sample to describe overall program outcomes. Second, in a subset of students with matched exit ticket and take-home survey data ($N=184$, 38%), bivariate analyses (χ^2 tests, t tests, correlations) examined associations between program-day responses and follow-up survey outcomes. These results were used to inform analysis of covariance (ANCOVA) models assessing the relationship of exit ticket indicators to inventive learning attributes, STEM belonging, and STEM interest, adjusting for demographics to account for social effects. All analyses were conducted using SPSS version 29.

To add depth and insight into students' experiences of the program, open-ended responses to the prompt "My favorite part of today was..." were content-coded, using the eight Mind of a Maker "Inventive Learning" constructs: imagination, reflection, perseverance, exploration, initiative, teamwork, perspective-taking, and skill-building. Although students could respond in their preferred language (English or Spanish), the vast majority (95%) provided responses in English and only English-language responses were included in the analysis. Following the methodology of Yue and colleagues, a large language model (LLM) software served as an initial coding step, with the analysis conducted in a confirmatory manner since the categories, their definitions, and contextual information about field trip activities were provided in advance [26, 27]. The LLM assigned each response to one of the five categories or labeled it

“unable to categorize.” Two independent staff coders then reviewed the LLM-generated assignments, indicated agreement or disagreement, and compared their judgments with each other. A lead coder oversaw the process, and the team achieved 70% initial agreement before reconciling discrepancies through consensus. Final codes were then applied to the qualitative dataset.

Results

Student Demographics and Participation

Population-level characteristics are presented in Table 1, including the gender, racial, and ethnic composition of the combined $N=479$ students enrolled in the program. Of the total number of students enrolled in the participating four elementary schools, $N=432$ attended the YSP field trips. Among attendees, $N=306$ students (71%) completed an exit ticket identifying their affiliation with STEM careers. Although all four participating schools were asked to return take-home surveys, three did so successfully and one did not (lost in the mail). A total of $N=224$ surveys were returned and $N=198$ of which (88%) were successfully matched with an exit ticket.

Knowledge and STEM Identity and Engagement Outcomes

The post-program knowledge assessment demonstrated high levels of awareness and understanding, with most students correctly responding to items on cancer prevention (88%), cancer biology (91%), and immunology (96%). Exit ticket surveys indicated that nearly all students with complete responses reported practicing as a scientist ($N=302/306$; 99%) and an engineer ($N=296/306$; 98%). Additionally, inventive learning attributes were endorsed by 90% of students, feelings of belonging in STEM were endorsed by 92%, and STEM interest was endorsed by 81%.

Student Reflections: Evidence of Inventive Learning

Student reflections on the prompt “My favorite part of the day was...” provided rich qualitative insights into the ways in which students adopted inventive learning attributes throughout the field trip. Of the eight pedagogical constructs given to the LLM, five were sufficiently well-represented in the student reflections to be utilized

(Exploration, Initiative, Perspective-Taking, Skill Building, and Teamwork), whereas three were not (Imagination, Reflection, and Perseverance). In total, students provided $N=284$ responses, of which $N=271$ (95%) were in English and $N=13$ (5%) were in Spanish. Of the $N=271$ English responses, $N=238$ were codable and $N=33$ were not (e.g., “Lunch”). Among the codable responses, the largest share ($N=115$, 48%) reflected Initiative, where students described moments of transforming their ideas into action, often highlighting hands-on experimentation and self-driven discovery (e.g., “Building trash cans for the lake so no people pollute it”). Other frequent themes included Skill Building ($N=45$, 19%), in which students emphasized developing new proficiencies or problem-solving abilities (e.g., “Coding [a] robot”) and Teamwork ($N=40$, 17%), where they noted the value of collaboration and working toward shared goals (e.g., “Making a project with my friends”) Perspective-Taking accounted for $N=26$ (11%) responses, illustrating how students considered new viewpoints and connected their learning to broader experiences (e.g., “Learning to care for the environment”), while a smaller proportion ($N=12$, 5%) centered on Exploration and curiosity (e.g., “Investigating”). Together, the qualitative and quantitative findings indicate that students not only endorsed maker learning attributes at high rates but also described concrete experiences of taking initiative, building skills, collaborating, and exploring during the program.

Associations between Program Participation and STEM Outcomes

Among a subset of $N=184$ students with matched exit ticket and survey data, at the bivariate level, students who affirmed that they practiced being a scientist/engineer during the field trip reported significantly higher feelings of belonging ($t=-3.0$, $df=182$, $p=0.002$), STEM interest ($t=-2.1$, $df=182$, $p=0.02$), and inventive learning ($t=-3.9$, $df=182$, $p<0.001$) than those who did not. Three race- and ethnicity-adjusted ANCOVA models with outcomes of inventive learning attributes ($F=9.81$, $df=2$, $p<0.001$), feelings of belonging in STEM ($F=6.98$, $df=2$, $p=0.001$), and STEM interest ($F=4.88$, $df=2$, $p=0.009$) were all significant, accounting for 9%, 6%, and 4% of the variance, respectively. Findings indicated that students who reported that they behaved like a scientist or engineer during the program exhibited stronger inventive learning attributes ($F=16.19$, $df=1$, $p<0.001$), feelings of belonging in STEM ($F=9.65$, $df=1$, $p=0.002$), and STEM interest ($F=4.75$, $df=1$, $p=0.03$).

Discussion

This evaluation of the YSP provides evidence that early, hands-on STEM learning experiences can promote feelings of belonging, inventive learning, and STEM interest among students from MUA/P backgrounds. The findings align with prior research demonstrating that engaging children from underrepresented backgrounds in active, collaborative, and culturally relevant STEM experiences can support positive identity formation and increase the likelihood of long-term engagement in STEM pathways [1, 2, 4].

The high levels of comprehension and recall in cancer biology and prevention among participating students suggest that the YSP's integrated approach—linking cancer education with maker learning—effectively fosters understanding of biomedical and behavioral concepts in an accessible and developmentally appropriate manner. This is consistent with prior work showing that authentic, inquiry-based experiences can increase scientific literacy and promote curiosity among elementary-aged children [3, 5]. The inclusion of topics relevant to participants' communities (e.g., cancer prevention, environmental stewardship) may have further enhanced engagement and retention, supporting the role of cultural relevance in STEM pedagogy for youth from MUA/P [6].

Nearly all students reported feeling that they “practiced being a scientist or engineer,” which strongly predicted greater inventive learning, belonging, and STEM interest. These findings underscore the importance of identity-based approaches to STEM learning, suggesting that when students see themselves as active participants in science and engineering, they begin to internalize those roles [7]. The association between practicing STEM roles and feeling a sense of belonging supports the notion that self-perception as a scientist or engineer is a key mechanism for strengthening STEM identity [8, 9].

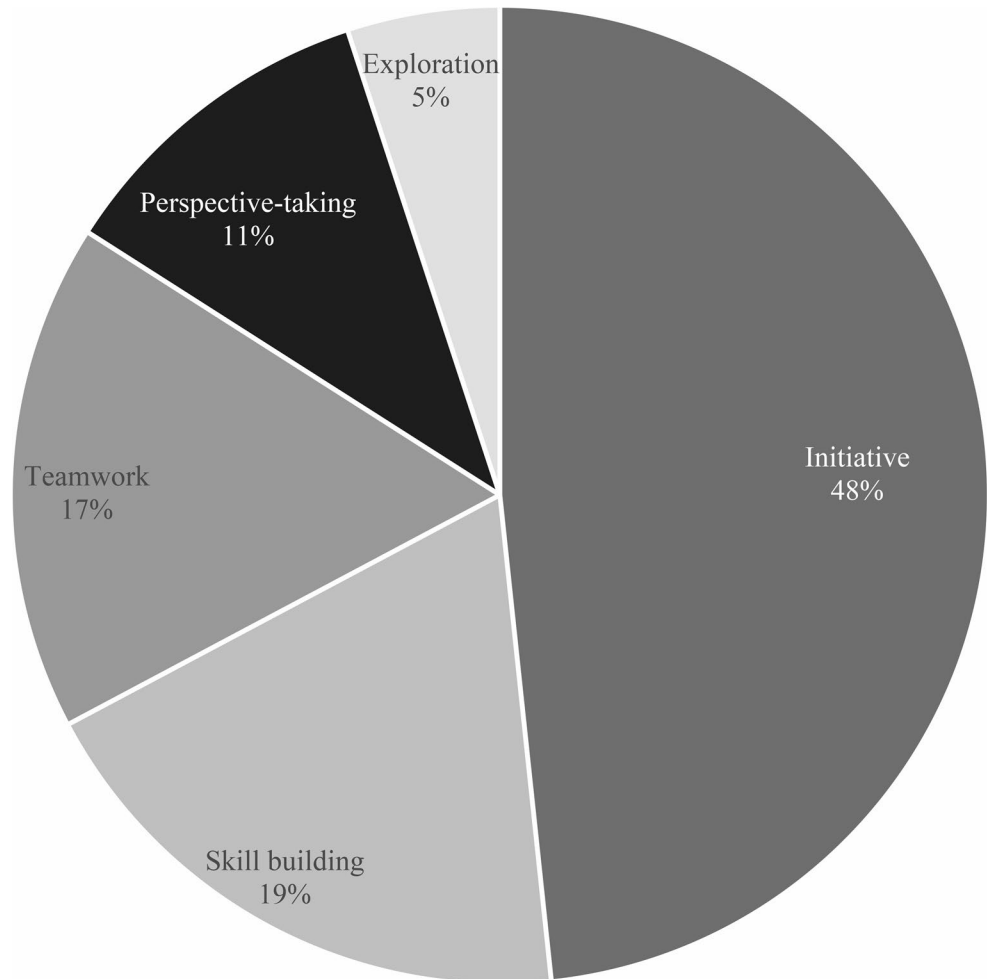
The qualitative findings provide additional insight into the nature of students' learning experiences. Reflections emphasizing initiative, skill building, and teamwork indicate that students not only learned content knowledge but also developed dispositions aligned with creative problem-solving and persistence—hallmarks of the maker learning philosophy [10]. These themes suggest that programs like the YSP may cultivate foundational competencies that extend beyond STEM, including collaboration, empathy, and agency [11]. The presence of perspective-taking in students' reflections also suggests that they were connecting

their learning back to broader societal and environmental contexts, an important component of equitable STEM education [12]. It is noteworthy that the concepts of imagination, reflection, and perseverance did not appear in these elementary students' brief, open-ended responses. Perhaps these constructs were more abstract, less immediately salient, and/or more difficult to articulate in short written answers to the evaluative prompt. These domains may also overlap, conceptually, with more concrete constructs such as initiative or skill building. Future research may help to better contextualize these findings and acknowledge possible developmental and methodological considerations in capturing such dimensions of students' inventive learning about STEM and cancer.

Importantly, the YSP's emphasis on belonging and representation may be especially beneficial for children from MUA/P, who often face structural barriers to STEM participation. By collaborating with a cancer center and a community-based museum, the program models an equitable partnership framework that bridges academic and informal learning environments. This structure not only enhances students' learning experiences but also provides a replicable model for community-engaged STEM outreach [13, 14].

Several limitations warrant consideration. First, the cross-sectional nature of the data precludes causal inferences, and longer-term follow-up is needed to assess sustained impacts on STEM identity and academic trajectories. Second, self-reported measures may be subject to social desirability or comprehension biases, although the use of visual Likert scales likely mitigated some of these effects. Third, only English-language qualitative responses were coded, potentially omitting nuances in Spanish-language reflections. Future evaluations should incorporate multilingual coding and consider mixed-method longitudinal designs to capture developmental changes over time.

Despite these limitations, the findings underscore the potential of the YSP to serve as an early intervention model to promote STEM identity, belonging, and health literacy among elementary school students from MUA/P. By integrating cancer content with maker learning, the YSP not only addresses educational inequities but also contributes to diversifying the future STEM and healthcare workforce. Continued investment in similar programs, paired with systematic evaluation and community co-design, have the potential to advance both educational equity and population health outcomes (Fig. 1).

Fig. 1 Inventive learning reflections

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Authors' Contributions MRS coordinated the study, conducted data analysis, and led the drafting and revision of the manuscript. ENE and MB contributed to data collection and analysis. MMS assisted with project administration and manuscript review. RBR and CD provided conceptual guidance and critical review of the manuscript. JE, DJD, LM, DS, and CJS contributed to program design, implementation, and data collection through the KID Museum partnership. KPT conceived and supervised the study, secured funding, and provided overall direction and manuscript oversight. All authors read and approved the final manuscript.

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Data Availability The datasets generated and/or analyzed during the current study are not publicly available due to restrictions related to participant privacy and school-level data sharing agreements.

Declarations

Competing interests The authors declare that they have no competing interests.

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